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THE DEVELOPMENT OF FLOATS AND EQUIPMENT FOR RESEARCH IN PROMOTING IT

By Wilhelm Pabst

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By Wilhelm Pabst

If one considers the float systems now in use one is impressed by the extraordinary multiplicity of types, not only in the methods of stabilization but also in the shape of the floats themselves. This multiplicity of types is certainly far from evidence of a high stage of development. It seems more probable that the multiplicity of technical types for the same purposes indicates that lack of experience and thorough knowledge still prevents a decisive judgment as to this or that type.

In the course of time increases in operating experience and in knowledge, as a result of theory and research, will make possible an appraisal for which the bases are today entirely lacking. In the following discussion I would like to present, from the point of view of a research engineer, the research methods which would make it possible to accelerate this development radically while avoiding errors and saving money.

I can safely assume that the questions which must be considered in connection with a float are known. It is a peculiarity of all these questions, take-off, landing shock, drifting, maneuvering, stability, etc., that although they can be treated separately they must always be considered as a whole for each influences the other to an extent which is not common in engineering. I need only refer to the questions of take-off resistance and landing impacts.

Consequently, in order to investigate a single characteristic of floats, the take-off, the H.S.V.A. was under the necessity of providing facilities not only for the study of the take-off resistance but also for the study of the drifting, maneuvering, and stability, and above all for the study of landing impacts.

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*"Schwimmwerkentwicklung und ihre versuchstechnischen Hilfsmittel. Z.F.M., December 14, 1932, pp. 681-686.

A further peculiarity of most of the float problems which, of course, they share with other problems in the field of research on flow, is that for the development of types a rather considerable number of special investigations is necessary. This necessity for studying a large number of constructional forms, and for studying them in several directions, for instance, with reference to take-off, maneuvering, drifting, landing impact, stability, and air drag, in order to develop a successful float, compels us to consider the economy of such tests, frequently purely routine, especially when the high installation and operating costs of the equipment are considered. Otherwise the comprehensive experimental development of a float may be wrecked on the high cost. In the following discussion of the separate problems you will also see how we of the H.S.V.A. have endeavored to reduce the cost of testing by adapting the construction of the testing equipment to more extensive tests of the individual float.

DETERMINATION OF TAKE-OFF RESISTANCE

The determination of the take-off performance by model tests may be assumed to be well known. I should like to refer especially to a paper by Paul Schröder (reference 1) that discusses the determination of take-off performance by model tests in a comprehensive manner.

Present-day towing tests of floats are notable for the exact account taken of the air forces and the air moments that are exerted on the float by the wings and control surfaces of the aircraft and that influence the draft and trim in a manner that is reflected in the resistance of the float. As the air forces and air moments are dependent not only on the speed itself but also on the angle of attack, that is, on the trim, it becomes necessary in towing tests either to control the lift and moment in their dependence on the speed and trim as required by the polar of the respective aircraft and the additional propeller and control surface forces and moments, or else to make a very large number of measurements for different lifts and different moments and later to interpolate for the airplane in question. Let me remark, briefly, that the first special method is very difficult technically but would very quickly give the take-off performance for definite conditions of installation in a given airplane. The other more general method requires very extensive tests but in exchange makes it possible to determine the take-off performance of any desired airplane for any desired conditions of installation.

In the course of time there has arisen from the tests of Schröder and Sottorf a compromise between the general and the specific methods. The lift is prescribed for a selected trim angle, corresponding to the polar, and during the test run this angle is held to by varying the applied moments. After tests have been made at a series of angles the actual running angle for the given control surface moments can be determined and the corresponding resistances can be tabulated to ascertain the take-off performance.

The new test equipment in the new Tank of the H.S.V.A. (reference 2) takes account of these previously applied methods in that runs can be made with the model free to trim and during a run the model can be set at the trim angle for which the lift is given, by shifting a sliding weight. Moreover, the test is made not by varying the moment during the run until the desired trim angle is reached but rather by predetermining the trim angle for which the lift is also predetermined, in this way running at fixed trim angles but free to rise, and measuring the moment.

Naturally, in the end it amounts to the same thing but the latter method has important practical advantages. As, in contrast with the actual airplane, stabilizing moments are not present and even the running of a model in fixed positions favors the development of disturbing oscillations, particularly oscillations in pitch, the floats usually run quite unsteadily, which - especially with the very large-scale models that are desirable - is very inconvenient, makes the setting at the mean trim angle very difficult and thus affects the measurement of the resistance. Furthermore, at high speeds the short time available for taking readings may not always be sufficient for setting the correct trim angle.

Figures 1 and 2 show the new test set-up. Lift is usually applied over the center sheave a. The moment can be predetermined for a run free to trim by shifting the running weight b on the moment beam c. This moment beam is pivoted on a slide d that can move on a vertical rail on ball-bearing rollers. This made it possible to obtain a convenient reading of the rise at actual scale e, and of the trim angle at a magnified scale f. If it is desired to run at fixed trim it is only necessary to clamp the moment beam to the slide by a coupling arm g. The trim is then set by turning a threaded shaft h by a hand crank. The moment is measured by measuring, or as proposed for the future, registering, the difference in the journal loads on the two sheaves, forward and aft, by hydraulic capsules i and the mercury manometer k.

The apparatus has proven itself satisfactory for the purposes intended. Subjective influences such as the manual skill of the test personnel are very largely neutralized and the notably quieter condition of the model, free to rise, makes possible the accurate measurement of the resistance even at high speeds. The great rapidity of measurement has been especially advantageous. It was even possible at quite high test speeds to make observations at three or four different angles. At constant lift that means that several wing settings can be studied simultaneously and that therefore in the same testing time as before at least twice as large a program of tests can be carried out.

It may be mentioned that the weight of the moving parts of this apparatus is no greater than when running free to trim and that the friction of the slide, thanks to suitable construction, can be neglected. In the design of this apparatus Messrs. Görrissen and van der Smissen supplied valuable cooperation.

THE DETERMINATION OF THE MANEUVERING CHARACTERISTICS OF THE FLOAT

It is required of the seaplane that it maneuver satisfactorily on the water, that is, that in a moderate wind it shall taxi on any course with course stability and shall be able to change its course. It appears more important that the aircraft shall be able to drift satisfactorily, that is, that with a free rudder and engines stopped, it shall head into the wind of itself, just as a sailboat must be weatherly to avoid broaching to and rolling over, that is, with rudder left free it must head into the wind. The behavior of the aircraft while being towed is also of interest.

If one limits oneself to the approximate appraisal, determination and possible improvement of the maneuvering characteristics of a design in the static condition, that is, steady taxying on smooth water, elementary mechanics at once determines the conditions. To begin with the vectorial sum of all the air and water forces that are exerted on the float and seaplane must be zero. The air forces are the propeller thrust and the aerodynamic drags that are exerted by the resultants from wind and air speed. The fulfillment of these requirements requires that with lateral wind components there shall also be lateral opposing forces on the float. To generate these lateral water forces the aircraft must make leeway so that the water flows at an angle against the float and thus produces the lateral forces required by the preceding conditions. The condition of directionally stable (course stable) taxying also requires that for a possible lateral movement of the rudder the sum of all moments, both the water and air force moments, shall be zero and that the derivative of the moment with respect to the course angle shall be negative.

The Towing Basin therefore is confronted with the task of determining the three components of the horizontal water forces that act on the float as the water flows against it at different angles at various speeds and possibly also at various transverse and fore-and-aft moments. These figures make it possible, if the required air forces on the parts above water also are known from wind-tunnel tests, to obtain the drift angle and the necessary rudder setting for a prescribed propeller thrust and course relative to the wind and in addition, to determine the course stability and maneuverability.

Simple as the mathematical statement of the problem is, the actual experimental and mathematical solution of the problem is just as time-consuming and expensive, for the different possibilities of obtaining a better maneuverability by variations of throttle and movements of rudder or elevator must be taken into account, not only in the model basin but most of all in the wind tunnel, by a very large number of series of tests. However, it is possible to derive coefficients from the experimental lateral forces and yawing moments, taking account of the lateral areas of the parts above water and of the rudder of the aircraft, that taken together with experience with similar aircraft make it possible to render an opinion as to whether the float design under consideration will have good or bad maneuvering qualities.

It seems doubtful whether the problem justifies such elaborate wind-tunnel tests, especially because the simple fitting of a water rudder will improve the maneuvering qualities so greatly that they will satisfy even severe demands.

It seems much more important to investigate the drifting of seaplanes because the safety of the aircraft depends on this to a high degree. The mathematical requirements are the same as for maneuvering, but it is necessary to tow the model stern first at various angles of yaw because the seaplane drifts astern. Here the measurement of the yawing moment and the resistance would suffice to check the stability requirements and to determine the speed of drifting. Aerodynamically the problem is considerably simpler and the practical execution of the investigations is entirely possible and is recommended for new designs, especially in connection with investigations of stability.

Figure 1 shows schematically the apparatus of the H.S.V.A. for measuring lateral forces; figure 3 is a photograph of it. The float model is fitted with a so-called model head (l) that carries a horizontal bar (m) that is adjustable about the vertical axis. This bar is guided so as to be in the direction of motion by the guide bars (n) which are also used in the ordinary towing tests. The guide bars are fitted in such a manner that they can move laterally and, if the model has been set at an angle of yaw, by adjusting at the model head, they support the forces forward and aft on hydraulic capsules (o). A special advantage appears to be that the lateral force tests can follow directly after the take-off tests without altering the test apparatus and consequently by better operation of the towing basin and the avoidance of fitting new apparatus, time and money can be saved to the advantage of a more comprehensive test program.

THE DETERMINATION OF LANDING IMPACT

Two years ago I had the honor of reporting to you regarding work on this problem. Permit me to refer to it here (reference 3).

Experimentally the problem is not so simple because the model tests should be conducted not according to Froude's Law but according to Cauchy's Law of Similarity, that, among other things, requires an elastic similarity between model and full size, which can hardly be accomplished practically with models of the usual scales. The recognition of this led to full size tests on actual aircraft. The forces at take-off and landing in a seaway were measured using a stress recorder especially designed for the purpose. It was found possible, along with the obtaining of numerical results, to check theoretical computations to a certain point as well as to draw conclusions as to the validity of assumptions made for the computations. Above all, the tests produced suggestions for the further treatment of the problem.

However valuable and necessary the experimental possibility is of making full size tests, it is equally unsatisfactory if one is restricted to it alone. Apart from the high costs, the experimental difficulties and also the risk to personnel and machines, the uncertainties of the external conditions, for instance, seaway and method of landing, impair the experimental accuracy of full size tests, especially if one desires to learn, for example, if and by how much one or the other form of bottom or float construction reduces the landing shock or if one desires by systematic stress measurements to reduce the weight of a float construction. There consequently arose the desire to produce methods of testing that, based upon the laws of similarity, could give the information required for the development of seaplane floats exactly, quickly, and cheaply from laboratory tests.

The theories used in the theoretical analysis had been shown to be admissible by the full size tests and could be used as a basis for the proposed model tests.

It can be imagined that the heavy landing impacts considered in the assumptions as to loads are produced by a part of the planing bottom striking the water normal to the keel with simultaneously uniform velocity over the whole area. With the help of this theory and some further considerations the problem can be divided into:

1. The determination of the impact forces, pressures, and stresses produced by the vertical dropping of a caisson constructed similarly to a full-sized float with predetermined bottom areas under impact and at various speeds of impact.

2. The determination of the "bottom length under impact" and the speed of impact as related to seaway and method of landing in full scale or in model basin tests.

The drop-testing apparatus (fig. 4) is intended for first tests.

A caisson constructed like a full-sized piece from the mid section of the float being studied, the length of which corresponds to the length of bottom of the float under impact in a definite seaway, is dropped onto the water surface from different heights in such a manner that the keel or the whole bottom area strikes the water simultaneously. The caisson, having the weight of the full-sized float is loaded to correspond with the gross weight of the aircraft with a definite spring system interposed. The springs correspond to the natural elasticity of the aircraft.

The weight slides in a guide. The determination of the impact forces is done by recording the shortening of the springs on impact. The speed of descent is determined by plotting a time-distance curve. The description of further details must remain for a later publication. However, I would like to state that the structural development of the design was in the hands of Mr. Görrissen.

With this equipment we hope to be able to clear up a series of important questions. Primarily, comparative measurements are to be undertaken to check and complete the theories regarding the influences of bottom form, dimensions, landing speeds, mass distribution, elasticity, structural arrangement, and materials.

Studies of the strength of float structures are another extensive and important field, for the purpose of making it possible, by means of a better use of materials to construct the float either stronger for the same weight or lighter for the same strength.

Primarily bottom pressure recorders and stress recorders will be used, both of which work on the scratching on glass principle, that is, the bending of the measuring disk or the extension of the material is recorded by a scratch on a revolving plate of glass and later interpreted under a microscope (figs. 5, 6, and 7).

In connection with the strength computations for seaplanes, there is still lacking a knowledge of the length of bottom under impact and the angle of impact as affected by the seaway and the type of landing. With certain precautions, tests in a model tank will answer if, - as in the H.S.V.A. - a wave-making device is available. As the quantities to be obtained depend principally on the geometric relations of the seaway and the dynamic properties of the airplane, but elasticity plays hardly any part, model tests in a tank even at small scale are feasible. If I am as yet unable to demonstrate it, nevertheless the development of this type of test is desirable as only model tests make it possible to make predictions regarding impact loads, for instance, on supporting structure, stub wings, etc., and their most favorable location.

There still remains a large field for full size tests. Above all, the necessity for also checking the convertibility of model tests led the H.S.V.A. to propose full size tests. In these again stress measurements are required.

Figure 8 shows a device developed by the H.S.V.A. that records on a glass cylinder by means of a diamond. I need not discuss the fundamentals of the method again (reference 4). As this device was intended mainly for tests on ships, emphasis was placed on a long period of operation as well as great sensitivity. Accordingly, in addition to direct recording without levers, recording with a lever transmission is also provided, which makes it possible to reach the same sensitivity with steel as with duralumin with its small modulus of elasticity. The lever transmission has demonstrated itself to be entirely practical in measuring landing impacts, hence at rather high frequencies.

Special importance has been attached to simple and light construction as well as good serviceability. The attaching points lie close above the knife edges so that any distortion of the device in fixing in position is avoided.

I would like to discuss more completely another and, as it seems to me, more substantial aid in the consideration of float problems. In the most varied problems of seaworthiness one is concerned with the idea of seaway.

The estimation of seaway, as it has been taken over from surface navigation, does not seem to me to be satisfactory any longer for seaplanes. These seaway figures require at least a clear definition, perhaps which seaway figure should correspond to certain definite wave heights, either mean or maximum, and which wave lengths should be considered as normal. Departures from the wave lengths should then be indicated by the seaway figures with "short", "very short", "long", or "very long". Above all we need such a definition of seaway if we are to make seaworthiness tests in the tank and are to make the seaway correspond to the model.

A seaway measuring device that has been designed and developed by the writer in two forms may serve for fundamental studies of this kind, as well as for supplementary tests in full-scale work. The principle of the device is as follows:

A buoy, anchored or secured to an accompanying craft, floats on the surface. This buoy will follow the movements of the water surface and rise and fall corresponding to the waves. To record the motions of this buoy it is necessary to have a fixed point, which is difficult to create in very deep water.

The difficulty is avoided by making use of the fact that disturbances of the surface die away rapidly downward and at a certain distance below the surface, are practically zero. Accordingly a pressure measuring device is suspended from the buoy (fig. 9) and follows the movements of the buoy. Now as the pressure on the measuring device is not affected by the motion of the water surface, if the cable is long enough, the pressure differences measured are proportional to the static pressure heights, that is, to the movements of the device with the buoy and hence the wave heights. From the variation of the pressures with time the wave lengths can be determined directly.

Two devices have been developed by the writer according to this principle, of which the one, built by the DVL, records directly by scratching on glass and has a clockwork drive; the other, developed at the H.S.V.A., is fitted with electrical remote indication so that even with a more exposed buoy the wave heights can be determined.

Herr Dipl.-Ing. Mewes tested the DVL device on the Müggel-see near Berlin and determined its usefulness and accuracy of indication. To him and to the DVL, I am indebted for courteously supplying figures 10 and 11.

The H.S.V.A. device (fig. 12), that depends on the variations in resistance with the flow of a current through an electrolyte, was tested in the towing basin in an artificial seaway. Again the indications were correct.

Further details must wait until later, after we have made a greater number of readings with the device. We hope, in this manner, to supply the basis for a clear definition of seaway.

In closing, let me point out briefly the objectives that at present stand in the foreground of the subject of research on float systems.

The possibility of determining in advance by model tests the get-away characteristics of a design will avoid the disagreeable surprises of earlier days. Why, the take-off problem itself might produce hardly any difficulties if the form did not have such a great effect on the loads on the float as well as on the whole aircraft. The increases in wing loadings and therewith of landing speeds, have more and more led to endeavors to reduce the landing impact of the previously common flat bottom. The planing bottom has been given a vee form which, however, with the higher propeller thrusts of modern aircraft did no important harm, but which produced heavy spray. Changes in the bottom intended to overcome this, for instance, fillets or wave-deflecting shapes or the like, again increase the impact in a manner previously unknown. Other methods for the same purpose are longitudinal steps, springing of the float struts or the bottom.

To provide fundamental information that will make possible a favorable compromise between landing impact and planing resistance is the immediate problem in experimental float development.

For this purpose the dropping tests with the equipment described above will serve as an extension of the planing-surface tests made some time ago (reference 5). The planing-bottom forms found suitable will then be expanded to floats by systematic tests, in which account will be taken not only of take-off characteristics but also of drifting, maneuvering, and stability.

Other important questions can be cleared up with the test equipment that has been described. We hope that by such comprehensively planned systematic float tests, it will be possible to promote development considerably and to approach nearer to the final objective of the seaworthy seaplane aerodynamically on a par with the landplane, without having had accidentally favorable or unfavorable results in operation with one or the other float leading the development astray.

Translation by Starr Truscott,
National Advisory Committee
for Aeronautics.

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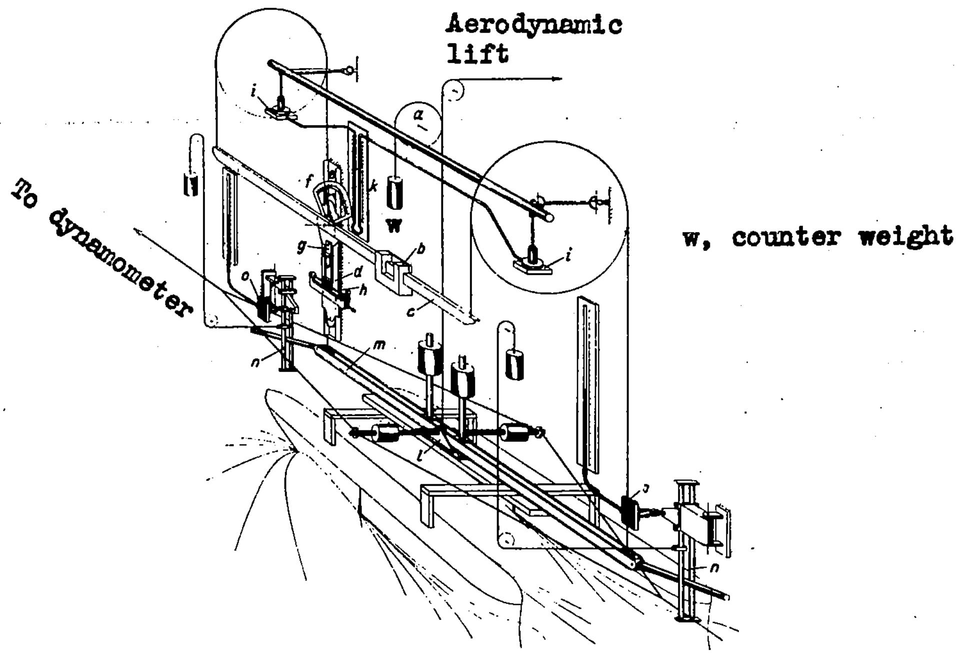

Figure 1.-Diagram of the test apparatus for take-off investigations.

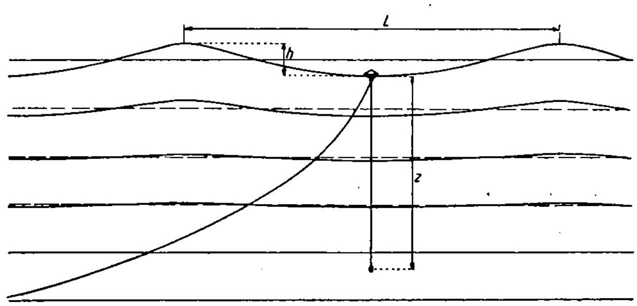

Figure 9.-Diagram showing the method of measuring seaway.

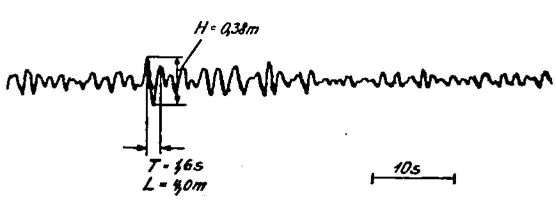

Figure 11.-Wave height record.

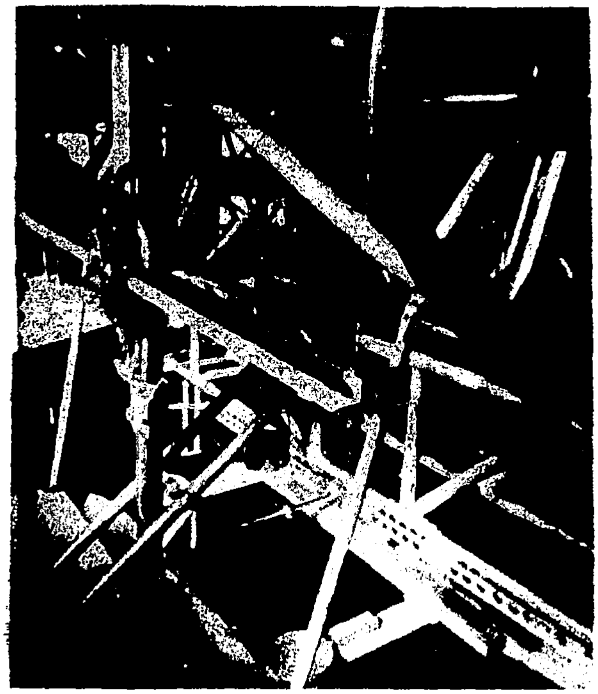

Figure 2.-Test apparatus for take-off investigations.

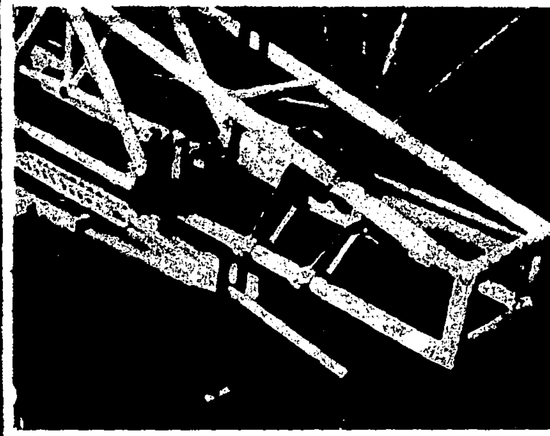

Figure 3.-Apparatus for measuring transverse forces.

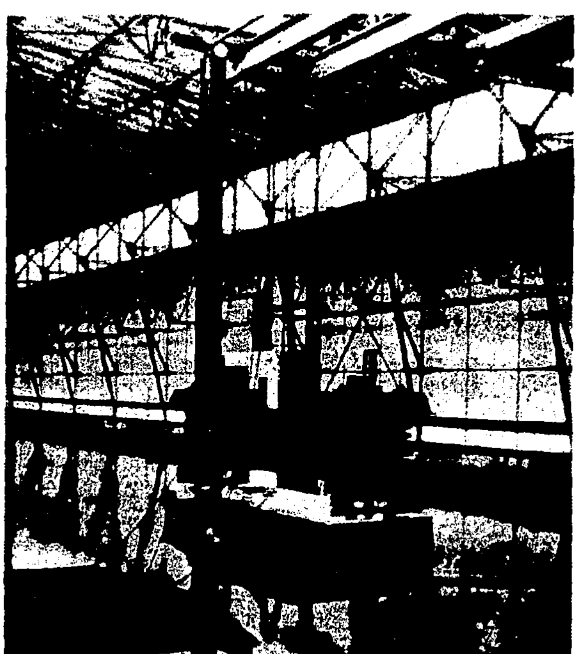

Figure 4.-Drop test apparatus for study of landing impact.

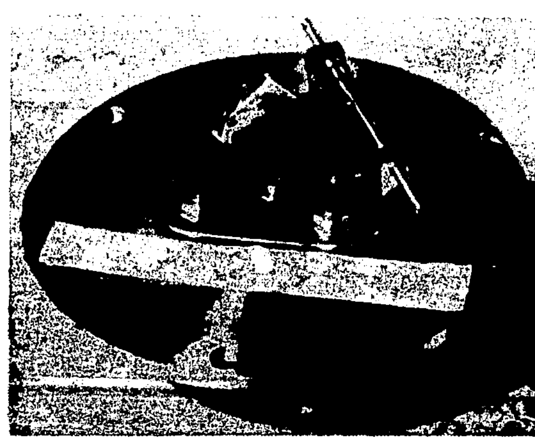

Figure 5.-Bottom pressure recording device.

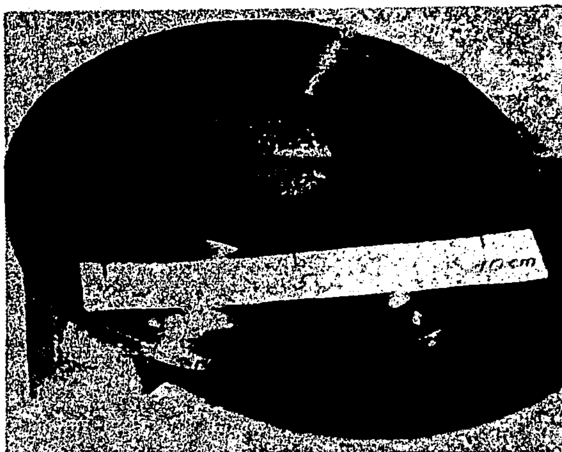

Figure 6.-Capsule for bottom pressure recording device (to be secured on the lower side of the float bottom).

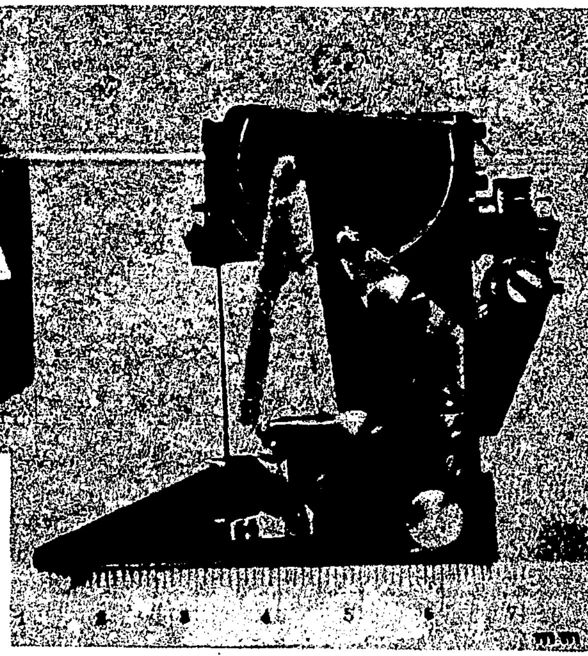

Figure 7.-Recording extensometer for short gauge lengths.

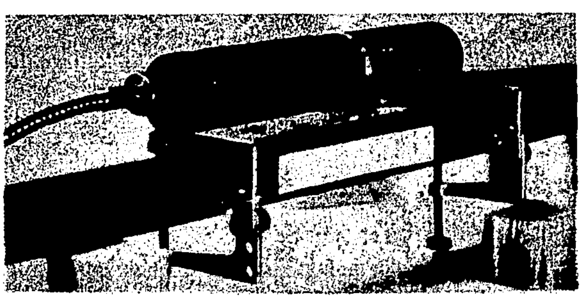

Figure 8.-Extensometer recording for a long period.

Figure 10.-Seaway measuring device with direct recording (D.V.L.).

Figure 12.-Seaway measuring device with remote indication (H.S.V.A.).